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R. D. NEIFELD

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US ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
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TABLE OF CONTENTS

TECHNICAL REPORTS 1998

REPORT NUMBER	TITLE	AUTHOR	DATE
ARCCB-TR-98001	Elastic Comparison of Four Thread Forms	G.P. O'Hara	Feb 1998
ARCCB-TR-98002	The Effect of a Curing Agent and an Accelerator on the Glass Transition of Brominated and Unbrominated Diglycidyl Ether of Bisphenol A	M.F. Fleszar	Mar 1998
ARCCB-TR-98003	Texture Analysis of $CoGe_2$ Alloy Films Grown Heteroepitaxially on GaAs(100) Using Partially Ionized Beam Deposition	K.E. Mello S.L. Lee S.P. Murarka T.-M. Lu	Apr 1998
ARCCB-TR-98004	Grain Orientations in Electrolytic High Contraction and Low Contraction Chromium Deposition	S.L. Lee D. Windover K.E. Mello	Apr 1998
ARCCB-SP-98005	Index to Benet Laboratories Technical Reports – 1997	R.D. Neifeld	Apr 1998
ARCCB-TR-98006	Compressive Thermal Yielding Leading to Hydrogen Cracking in a Fired Cannon	J.H. Underwood A.P. Parker P.J. Cote S. Sopok	Apr 1998
ARCCB-TR-98007	Residual Stress in a Swage Autofrettaged Steel Cylinder with Semi-Circular Mid-Wall Channels	S.L. Lee E. Hyland J. Neese D. Windover	May 1998
ARCCB-TR-98008	$(l/F)^n$ Electronic Flicker Pulsing	M.A. Johnson P.J. Cote	May 1998
ARCCB-CR-98009	Stability of Arrays of Multiple-Edge Cracks	A.P. Parker J.H. Underwood (Benet POC)	Jun 1998
ARCCB-TR-98010	The Bauschinger Effect in Autofrettaged Tubes – A Comparison of Models Including the ASME Code	A.P. Parker J.H. Underwood	Jun 1998
ARCCB-TR-98011	X-Ray Determination of Texture and Residual Stress in Low Contraction Electrolytic Chromium Deposition	S.L. Lee D. Windover	Jul 1998
ARCCB-TR-98012	Phase, Residual Stress, and Texture in Triode-Sputtered Tantalum Coatings on Steel	S.L. Lee D. Windover	Jul 1998
ARCCB-TR-98013	Dynamic Modeling for Design: Space-Time Finite Element Formulation of an Euler Beam	E.L. Kathe	Jul 1998
ARCCB-TR-98014	Failure Analysis of an 84-mm, M3, Carl Gustaf, Recoilless Rifle	K. Miner A. Kapusta K. Olsen	Jul 1998

TECHNICAL REPORTS 1998

REPORT NUMBER	TITLE	AUTHOR	DATE
ARCCB-TR-98015	Use of the Instrumented Bolt and Constant Displacement Bolt-Loaded Specimen to Measure In Situ Hydrogen Crack Growth in High Strength Steels	G.N. Vigilante J.H. Underwood D. Crayon	Aug 1998
ARCCB-TR-98016	The Role of Vanadium Carbide Traps in Reducing the Hydrogen Embrittlement Susceptibility of High Strength Alloy Steels	G.L. Spencer D.J. Duquette	Aug 1998
ARCCB-TR-98017	The Cannon-Projectile Blow-By Flow Field	C.A. Andrade A. Cunningham H.T. Nagamatsu D.G. Messitt	Sep 1998
ARCCB-TR-98018	Comprehensive Erosion Model for the 120-mm M256/M829A2 Gun System	S. Sopok P. Vottis P. O'Hara G. Pflegl C. Rickard	Oct 1998
ARCCB-TR-98019	Shot-by-Shot Erosion Modeling of Retired 120-mm M256 Gun Tube #1988	S. Sopok P. Vottis P. O'Hara G. Pflegl C. Rickard	Oct 1998
ARCCB-TR-98020	Comprehensive Erosion Model for the 120-mm M256/M829 Gun System	S. Sopok P. Vottis P. O'Hara G. Pflegl C. Rickard	Dec 1998

AUTHOR INDEX 1998

AUTHOR	REPORT NUMBER
Andrade, C.A.	ARCCB-TR-98017
Cote, P.J.	ARCCB-TR-98006 ARCCB-TR-98008
Crayon, D.	ARCCB-TR-98015
Cunningham, B.	ARCCB-TR-98017
Duquette, D.J.	ARCCB-TR-98016
Fleszar, M.F.	ARCCB-TR-98002
Hyland, E.	ARCCB-TR-98007
Johnson, M.A.	ARCCB-TR-98008
Kapusta, A.	ARCCB-TR-98014
Kathe, E.L.	ARCCB-TR-98013
Lee, S.L.	ARCCB-TR-98003 ARCCB-TR-98004 ARCCB-TR-98007 ARCCB-TR-98011 ARCCB-TR-98012
Lu, T.-M.	ARCCB-TR-98003
Mello, K.E.	ARCCB-TR-98003 ARCCB-TR-98004
Messitt, D.G.	ARCCB-TR-98017
Miner, K.	ARCCB-TR-98014
Murarka, S.P.	ARCCB-TR-98003
Nagamatsu, H.T.	ARCCB-TR-98017
Neese, J.	ARCCB-TR-98007
Neifeld, R.D.	ARCCB-SP-98005

AUTHOR INDEX 1998

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SUBJECT INDEX 1998

SUBJECT INDEX 1998

SUBJECT INDEX 1998

SUBJECT INDEX 1998

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REPORT NUMBER	AD NUMBER
ARCCB-TR-98001	A338 658
ARCCB-TR-98002	A338 695
ARCCB-TR-98003	A342 320
ARCCB-TR-98004	A342 324
ARCCB-SP-98005	A342 997
ARCCB-TR-98006	A344 812
ARCCB-TR-98007	A346 749
ARCCB-TR-98008	A348 335
ARCCB-CR-98009	A348 587
ARCCB-TR-98010	A349 152
ARCCB-TR-98011	A350 268
ARCCB-TR-98012	A350 108
ARCCB-TR-98013	A350 722
ARCCB-TR-98014	A352 481
ARCCB-TR-98015	A353 523
ARCCB-TR-98016	A354 284
ARCCB-TR-98017	A354 740
ARCCB-TR-98018	A356 146
ARCCB-TR-98019	A355 855
ARCCB-TR-98020	A358 731

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13. ABSTRACT (*Maximum 200 words*)

Previously, this author introduced the concept that all screw thread forms have a structural "Characteristic Curve," which defines the basic stress concentration as a function of a radial stress in the joint. An additional set of characteristic curves is produced when the general stress field is considered. The standard analysis is for a single-thread tooth, isolated from a long chain of identical teeth, that is computationally efficient and facilitates the calculation of a family of characteristic curves. This work presents the characteristic plots for four different threads, the 7-degree British buttress, a 15-degree asymmetric "V," the 20-degree Benet buttress, and a special 30-degree "V." These four threads were selected because they are or may be useful in high pressure systems. Together they suggest the possibility of a standard thread family for high pressure applications.

14. SUBJECT TERMS

Screws, Screw Threads, Thread Forms, Threaded Connections,
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Dicyandiamide—a solid with a melting point of 209°C—is one of a unique group of curing agents that are insoluble in epoxy at room temperature. As a curing agent for epoxy resins, dicyandiamide can react through all four nitrogen groups—reacting with the resin at both epoxide and hydroxyl sites. When mixed with either diglycidyl ether of bisphenol A or diglycidyl ether of tetrabromobisphenol A, the formulation is stable enough to be stored for 6 to 12 months. Because dicyandiamide's solubility is low at room temperature, the curing reaction is limited until the temperature increases enough to dissolve the curing agent. To improve the ability to process the resin, an accelerator (such as diuron) can be added to reduce the curing temperature. The curing reaction then proceeds via a complex mechanism that is not dominated by a single reaction. Each compound's effect on the cured material was studied by measuring changes in the glass transition temperature.

14. SUBJECT TERMS
Curing Agents, Accelerator, Glass Transition, Epoxy, Resins, Diglycidyl Ether of Bisphenol A

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6. AUTHOR(S)
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13. ABSTRACT *(Maximum 200 words)*

Reflection X-Ray pole figure analysis techniques were used to study the heteroepitaxial relationships of the cobalt germanide $CoGe_2$ to GaAs(100). The alloy films were grown using the partially ionized beam deposition technique, in which low energy Ge^+ ions are used to alter the heteroepitaxial orientation of the $CoGe_2$ deposits. The $CoGe_2$[001](100)‖GaAs[100](001) orientation, which has the smallest lattice mismatch, occurred for depositions performed at a substrate temperature around 280°C and with ~1200 eV Ge^+ ions. Lowering the substrate temperature or reducing the Ge^+ ion energy leads to $CoGe_2$(100) orientation domination with $CoGe_2$[100](010)‖GaAs[100](001) and $CoGe_2$[100](001)‖GaAs[100](001). Substrate temperature alone produced only the $CoGe_2$(100) orientation. For $CoGe_2$(001) films, additional energy was required from Ge^+ ions in the evaporant stream.

14. SUBJECT TERMS
$CoGe_2$, Epitaxy, Texture, Partially Ionized Beam Deposition

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S.L. Lee, D. Windover, and K.E. Mello (RPI, Troy, NY)

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Several electrochemical deposition parameters affect grain orientations, which, in turn, affect coating quality and performance. An enhanced x-ray pole figure technique has been used to study grain distribution anisotropy in electrolytic high contraction (HC) and low contraction (LC) chromium. Temperature and current density are the most important factors controlling grain orientation. Production HC chromium deposited on steel at low temperature and low current density exhibited strong <111> fiber texture, while LC chromium deposited on steel at high temperature and high current density exhibited near random crystalline orientation. The drastic change in grain orientation on steel from strongly textured HC chromium to randomly oriented LC chromium is accompanied by marked differences in crack density, hardness, deposition rate, microstructure, thermal behavior upon heating and cooling, and improved wear and erosion performance. Laboratory LC chromium specimens that were deposited on copper plates with and without sample rotation and pulse current plating showed preferred (211) and (222) orientations. Although substrate material affects grain orientation, sample rotation and pulse current plating play a less important role.

14. SUBJECT TERMS
Chromium, Electrolytic, Contraction, Texture, Pole Figure, Orientation

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13. ABSTRACT *(Maximum 200 words)*

Investigation of environmental cracking of a 1100 MPa yield strength A723 steel cannon tube subjected to prototype firings is described. Metallographic results show cracking of the steel beneath a 0.12 mm protective layer of chromium. Cracks undermine and remove sections of chromium and lead to localized erosion that ruins the cannon. Key features of the firing thermal damage and cracking are: [i] recrystalization of the chromium to a depth of up to 0.08 mm; [ii] steel transformation to 0.19 mm below the chrome surface; [iii] two different periodic arrays of cracks normal to the hoop and axial directions, with mean depths of 0.23 and 0.46 mm, respectively.

Time-temperature-depth profiles for the firing cycle were derived via bi-material finite difference analysis of a semi-infinite solid which incorporated cannon combustion gas temperatures and material properties that vary as a function of temperature. The temperature and depth associated with the steel transformation were used to solve iteratively for the convective heat transfer coefficient. This value was further confirmed by the depths of chromium recrystalization and of the crack arrays in the two orientations. A profile of maximum temperature versus depth is used to determine the near-bore applied and residual stress distributions within the tube. The measured volume change of steel transformation is used to determine an upper limit on applied and residual stresses. These stresses are used to determine crack-tip stress intensity factors for the observed crack arrays and hence provide some explanation for the differential depths of cracking.

The near-bore temperature and residual stress distributions are used to help determine the cause of hydrogen cracking and measures to prevent cracking. Compressive yielding due to thermal loading produces near-bore tensile residual stresses and thereby causes hydrogen cracking. Prevention of cracking is discussed in relationship to hydrogen crack growth rate tests of alternative alloys and coatings.

14. SUBJECT TERMS
Thermal Yielding, Environmental Cracking, Hydrogen Cracking, A723 Steel, Cannon Tubes, Residual Stress, Stress Intensity Factors

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13. ABSTRACT *(Maximum 200 words)*

X-ray diffraction residual stress distribution analysis was performed for a swage autofrettaged, thick-walled, A723 steel compound cylinder with axial semi-circular mid-wall channels. Because of the existence of high stress gradient components in the stress distribution, the effect of spatial resolution and the x-ray beam spread function were investigated. Experimental stress measurements were compared with results from Tresca's model of a partially autofrettaged solid cylinder. Measured residual stresses were interpreted using an ABAQUS finite element model. Our experimental results verified most features of the predicted hoop stress distribution, including the high stress gradients and compressive stresses near the channel root areas. However, significantly reduced compressive stress levels were observed both near the bore and near the channel roots. An overestimate of fatigue lifetime could result if the reduction of compressive stresses observed experimentally were not taken into account. In solid autofrettaged cylinders, reduction of compressive stresses near the bore has been attributed to the Bauschinger effect. However, there is no analytical model incorporating the Bauschinger effect in the current geometry. This work demonstrated that the introduction of the semi-circular channels in a solid cylinder significantly modified the magnitude and location of stress fields. Both the bore and the channel roots are critical sites for stress concentration. Our analysis further determined that the channel roots were the most critical sites where cracks and failure should occur. Fatigue test results verified that cracking and failure occurred at the channel roots.

14. SUBJECT TERMS

Swage Autofrettage, Perforated Cylinders, Bauschinger Effect, Residual Stress, Finite Element Analysis

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13. ABSTRACT *(Maximum 200 words)*

Pulsing circuits generate electromagnetic interference (EMI) that can affect sensitive circuitry and adversely contribute to the spectral signature of equipment. "Flicker noise" concepts, derived from chaos theory, have been employed to efficiently pulse circuitry while generating a virtually undetectable spectral signature. Pure flicker pulsing requires that the components be driven with a set of uncorrelated pulses, with random heights, starting at random times. However, a significant reduction in conspicuous power spectral density (PSD) components can be achieved when imposing practical constraints. We have been able to significantly reduce the dominant components of the power spectrum using fixed pulse durations and magnitudes. We employed flicker pulsing, with a PSD approaching $(1/f)^2$, to drive our components more efficiently, resulting in a 40% increase in battery life. The contribution of the pulses to the spectral signature of the equipment appears only in the background noise of EMI detectors.

14. SUBJECT TERMS

Electromagnetic Interference (EMI), Chaos Theory, Flicker Noise, Electronics

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STABILITY OF ARRAYS OF MULTIPLE-EDGE CRACKS

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13. ABSTRACT *(Maximum 200 words)*

The creation and subsequent shedding of arrays of edge cracks is a natural phenomenon which occurs in heat-checked gun tubes, rapidly cooled pressure vessels, and rock, dried-out mud flats, paint, and concrete and in ceramic coatings and permafrost. The phenomenon covers five orders of magnitude in crack spacing. A simple model is developed which indicates that the shedding behaviour is governed by energy release from individual cracks rather than global energy changes. The model predicts that all cracks will deepen until a crack-spacing/crack-depth ratio (2h/a) of 3.0 is achieved, at which stage crack-shedding will commence. Two out of every three cracks will be shed, leading to a new (higher) crack-spacing/crack-depth ratio at which stage growth of all currently active cracks will be dominant.

An approach based upon rapid, approximate methods for determining stress intensity provides good indications of behaviour provided near-surface stress gradients are not excessive. In cases where stress gradients are high, it is shown that it is necessary to employ numerical techniques in calculating stress intensity. Two specific examples are presented, the first at very small scale (heat-check cracking, typical crack spacing 1mm) and the second very large scale (permafrost cracking, typical crack spacing 20m). The predicted ratios for the proportion of cracks shed and for crack-spacing/crack-depth are in agreement with experimental evidence for gun tubes, concrete, and permafrost. The ratios also appear to match experimental observations of 'island delamination' in ceramic coatings and paint films.

14. SUBJECT TERMS
Crack Arrays, Edge Cracks, Crack Shedding, Crack Growth, Fracture, Fracture Mechanics, Residual Stress, Stress Intensity Factor, Permafrost, Mud Flats, Gun Tubes, Concrete

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13. ABSTRACT *(Maximum 200 words)*
Autofrettage is used to introduce advantageous residual stresses into pressure vessels and to enhance their fatigue lifetimes. For many years workers have acknowledged the probable influence of the Bauschinger effect which serves to reduce the yield strength in compression as a result of prior tensile plastic overload. This in turn can produce lower compressive residual hoop stresses near the bore than are predicted by 'ideal' solutions (elastic/perfectly plastic without Bauschinger effect).

There have been several models proposed in order to predict the reduced stresses within the autofrettaged tube. The purpose of this paper is simply to compare a limited set of models, including the ASME code, with available experimental evidence. Three models are compared: Model A, based upon a quasi strain-hardening model developed by Chen; Model B, based upon a Bauschinger effect which varies with plastic strain and hence with radius; Model C, which is based upon section KD-522.2 of the recently revised ASME pressure vessel code. The models are compared against experimental data under three headings:

- Measurements of Hoop Residual Stress at the Bore
- Measurements of Hoop Residual Stress Variation Radially Through the Tube Wall, In Particular the Near-Bore Region
- Measurements of Opening Angle When Autofrettaged Tubes are Slit Radially, Hence Releasing the Pure Bending Moment 'Locked In' by the Hoop Stress

14. SUBJECT TERMS
Pressure Vessels, Autofrettage, High Strength Steel, Fatigue Life, Bauschinger Effect

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X-RAY DETERMINATION OF TEXTURE AND RESIDUAL STRESS IN LOW CONTRACTION ELECTROLYTIC CHROMIUM DEPOSITION

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13. ABSTRACT *(Maximum 200 words)*

Residual stresses are believed to be responsible for the intrinsic cracks observed in electrolytic chromium coatings. The cracks directly affect the wear and erosion behavior of the coating and substrate. Crystalline orientation significantly influences the elastic-plastic properties of materials. It also affects the method by which residual stress can be determined using x-ray diffraction. For this study, we investigated texture and residual stress analysis for two low contraction (LC) chromium coating specimens and compared the results with a high contraction (HC) chromium specimen. High-resolution pole figure analysis and x-ray diffraction were used to characterize the texture in the coatings. Randomly oriented materials allow the application of the x-ray diffraction $\sin^2\Psi$ stress measurement method. For highly textured body-centered-cubic crystals, the $\sin^2\Psi$ method failed, so a Matlab matrix inversion method was used to determine residual stress. One of the LC chromium specimens exhibited near random orientation with very weak fiber texture, and the other specimen exhibited intermediate mixed <111> and <211> fiber texture. The HC chromium specimen exhibited strong predominately <111> fiber texture. A correlation between residual stress and texture was found. The HC chromium specimen with high fiber texture showed higher surface tensile stresses, while the LC chromium specimens with more randomly oriented crystallites showed lower residual stresses.

14. SUBJECT TERMS

Chromium, Low Contraction Chromium, High Contraction Chromium, Texture, Residual Stress

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13. ABSTRACT *(Maximum 200 words)*
This work analyzes the unoptimized, prototype triode-sputtered, 150 μm thick tantalum coatings deposited with a 2.5 μm niobium under-layer onto the bore of a large-diameter A723 steel cylinder. The coating was deposited for wear and erosion protection by Pacific Northwest National Laboratory. Our phase determination was based on x-ray diffraction analysis, wavelength dispersive x-ray fluorescence analysis, energy dispersive x-ray analysis, and hardness and electrical resistivity measurements. Both x-ray diffraction and radius-of-curvature methods were used to determine residual stresses. A locally developed high-resolution pole figure technique was used to perform texture analysis. The post-firing, debonded coating showed alpha-tantalum, preferred [110] orientation, high surface stresses, tantalum oxides, entrapped krypton sputtering gas, interstitial oxygen, and other impurities. The surface and subsurface pole figures revealed broadened poles and body-centered-cubic tantalum crystalline structure.

14. SUBJECT TERMS
Residual Stress, Texture, Tantalum, Sputtered, Phase, Niobium, X-Ray Fluorescence, X-Ray Diffraction

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13. ABSTRACT *(Maximum 200 words)*

This paper demonstrates the application of finite element methods in both space and time to the partial differential equations that govern beam dynamics. The approach enables design problems for the structural response of beams subject to shock and vibration loading to be posed. Numerical validation of the results using a forward Euler ordinary differential equation solver is also shown.

14. SUBJECT TERMS
Structural Dynamics, Space-Time Finite Element Analysis, Optimal Design

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FAILURE ANALYSIS OF AN 84-MM, M3, CARL GUSTAF, RECOILLESS RIFLE

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13. ABSTRACT *(Maximum 200 words)*

During a February 26, 1997 training exercise at Fort Benning, Georgia, an 84-mm, M3, Carl Gustaf, shoulder-fired, recoilless rifle—the TACOM-ARDEC Multi-Role, Anti-Armor, Anti-Personnel Weapon System (MAAWS)—failed while firing an FFV552 training round. The composite-wrapped, steel-lined barrel burst open beneath the trigger housing—destroying the weapon but leaving the Gunner and Assistant Gunner uninjured. The rifle (serial number 14051) was evaluated in the field and at Benet Laboratories. Inspections included a bore surface inspection, dimensional checks, a magnetic particle inspection, an ultrasonic inspection, a crack evaluation, and a bore debris analysis. Although there is no clear evidence regarding the cause of the failure, the evidence does indicate that the failure may have been caused by a soil obstruction in the barrel. This obstruction probably produced a large amount of highly localized stress on the carbon fiber, composite-overwrapped, steel barrel—thereby causing the jacket that contains the pressure to fail and allowing the pressurized propellant gases to deform and rupture the underlying steel liner.

14. SUBJECT TERMS
Gun Failure, Carl Gustaf, MAAWS, M3, Composites, Composite Gun Barrels, Ultrasonic Inspection, Magnetic Particle Inspection, Scanning Electron Microscopy

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USE OF THE INSTRUMENTED BOLT AND CONSTANT DISPLACEMENT BOLT-LOADED SPECIMEN TO MEASURE IN SITU HYDROGEN CRACK GROWTH IN HIGH STRENGTH STEELS

5. FUNDING NUMBERS

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13. ABSTRACT (*Maximum 200 words*)

Aggressive environments experienced by large caliber gun tubes during processing and firing have lead to a great deal of investigation on the hydrogen-induced cracking susceptibility of high strength steels. The constant displacement bolt-loaded specimen has been used to determine the hydrogen crack growth rates and threshold stress intensity of AF1410—both conventionally and isothermally heat treated—and AerMet 100. Additionally, the severe susceptibility of high strength steels has necessitated the application and modification of a low cost, highly reliable, in situ crack measurement method, called the instrumented bolt. The instrumented bolt consists of a full bridge, strain-gaged stainless steel bolt coupled to an automatic data acquisition system. New expressions have been developed for use with the instrumented bolt and bolt-loaded specimen to relate load to crack growth. Our study determined that Stage II crack growth rates for the AF1410 were $1.1E^{-2}$ and $2.3E^{-2}$ mm/s for conventional and isothermal AF1410, respectively. Threshold stress intensity levels for AF1410 were 16.0 and 13.7 MPa $m^{1/2}$, respectively. Stage II crack growth rates for AerMet 100 were $2.4E^{-2}$ mm/s, while the threshold stress intensity was 14.1 MPa $m^{1/2}$.

14. SUBJECT TERMS

Hydrogen-Induced Cracking, Hydrogen Embrittlement, Environmental Cracking, Environmental Fracture, Instrumented Bolt, Bolt-Loaded Specimen, High Strength Steels, ASTM A723, AF1410, AerMet 100

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13. ABSTRACT (*Maximum 200 words*)

High strength alloy steels typically used for gun steel were investigated to determine their susceptibility to hydrogen embrittlement. Although AISI grade 4340 was quite susceptible to hydrogen embrittlement, ASTM A723 steel, which has identical mechanical properties but slightly different chemistries, was not susceptible to hydrogen embrittlement when exposed to the same conditions. The degree of embrittlement was determined by conducting notched tensile testing on uncharged and cathodically charged specimens. Chemical composition was modified to isolate the effect of alloying elements on hydrogen embrittlement susceptibility. Two steels—Modified A723 (C increased from 0.32% to 0.40%) and Modified 4340 (V increased from 0 to 0.12%)—were tested. X-ray diffraction identified the presence of vanadium carbide, V_4C_3, in A723 steels, and subsequent hydrogen extraction studies evaluated the trapping effect of vanadium carbide. Based on these tests, it was determined that adding vanadium carbide to 4340 significantly decreased hydrogen embrittlement susceptibility because vanadium carbide traps ties up diffusible hydrogen. The effectiveness of these traps is examined and discussed in this paper.

14. SUBJECT TERMS

Hydrogen Trapping, Vanadium Carbide Traps, Hydrogen Embrittlement of Steel, 4340 and Its Susceptibility to Hydrogen Embrittlement, Notch Tensile Testing, Vanadium Additions to High Strength Steel Alloys

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13. ABSTRACT *(Maximum 200 words)*

The objective of this work was to document the numerical simulation of the cannon-projectile blow-by flow for a Zone six firing of an M549A1 with XM230 charge. The steady, axisymmetric flow was determined by use of the NPARC Computational Fluid Dynamics Code, given inflow boundary values at points on the ballistics path. We computed pressure distributions on the projectile, assuming a smooth cannon surface. Integration of the distribution over the projected lateral surface of the projectile gives an estimated side force of 500,000 pounds on the projectile as it enters the brake section of the tube. In a yawed attitude, such forces can effect inertial instabilities on the projectile which, in turn, contribute to balloting and mechanical wear of the tube. The same numerical solution computes local heat transfer rates on the obturator and rotating band surfaces. The effect of blow-by flow heat transfer on tube ersoion is a factor that is not well understood. An extension of the present work will provide a basis for further understanding the combined effects of abrasive and chemical erosion. The present computations assume that the wear gap between projectile and cannon wall is 0.020 inch and that the obturator protrudes 70% into the gap. Results are presented at two points on the ballistics trajectory, 2.212 and 5.256 meters from the rifle origin. Local heat transfer to the barrel wall was obtained for projectiles with and without obturator and band. At the 2.212 meter location, the latter yielded maximum local heat transfer rates on the barrel surface that exceeded 30 times the heat transfer computed at 1.7 inches upstream of the projectile's base (i.e., in the projectile's wake boundary layer). With the obturator and band, and at the same travel point, the heat transfer ratio peaked at 2040, with the wake heat transfer computed at 6.7 inches upstream of the projectile's base.

14. SUBJECT TERMS
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Distinct erosion patterns and mechanisms are emerging as our gun erosion database increases for in-service and out-of-service 120-mm M256 tubes with M829A2 rounds. Variability exists for M256 guns with M829A2 rounds depending on round count, round type, round-conditioning temperature, and their order. Our M256/M829A2 gun system erosion model—with its interior ballistics, thermochemistry, and boundary layer components—is constantly being guided and refined by the erosion and materials analysis data from fired gun tubes. A recent refinement includes improvement of the gun steel subsurface exposure model due to high quality, difficult to obtain data from in-service M256 tubes. Other recent refinements to the boundary layer heat transfer model are based on thermal data from M256 tubes. These refinements include the improvement/incorporation of case gas cooling effects, turbulent gas mixing/heating effects, and a very minor contribution from forcing cone-induced vena contracta cooling effects. These latter refinements are calibrated away from crack walls by positional thermal wall repacking depth, thermal wall transformation depth, and thermocouple data. A comprehensive gun erosion model and multiple single-shot erosion condemnation predictions are described for the 120-mm M256 gun with its M829A2 round for hot-conditioned rounds only, ambient-conditioned rounds only, cold-conditioned rounds only, and an equal distribution of hot/ambient/cold-conditioned rounds. The gun erosion mechanism consists of heat checking the inert chromium plate, subsequent interfacial degradation of the subsurface gun steel substrate at the chromium crack bases, then chromium platelet spalling, and subsequent bare gun steel gas wash. This gun erosion model correctly calculates and predicts that the worst eroded region is at 1.2 to 2.4 meters from the rear face of the tube. The excessive muzzle wear is by a different, purely mechanical gas wash-free mechanism. Most importantly, given herein are the relative erosion-related effective full-charge values of the fielded M256 gun kinetic energy rounds at various round-conditioning temperatures.

14. SUBJECT TERMS
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As our gun erosion database increases for in-service and out-of-service 120-mm M256 tubes with M829Ax series rounds, distinct erosion patterns and mechanisms are emerging. Variability exists for M256 guns with M829Ax series rounds depending on round count, round type, round-conditioning temperature, and their order. Our M256/M829Ax gun system erosion model—with its interior ballistics, thermochemistry, and boundary layer components—is constantly being guided and refined by the erosion and materials analysis data from fired gun tubes. A recent refinement includes the improvement of the gun steel subsurface exposure model due to high quality, difficult to obtain data from in-service M256 tubes. Other recent refinements to the boundary layer heat transfer model are based on thermal data from M256 tubes. These refinements include the improvement/incorporation of case gas cooling effects, turbulent gas mixing/heating effects, and a very minor contribution from forcing cone-induced vena contracta cooling effects. These latter refinements are calibrated away from crack walls by positional thermal wall repacking depth, thermal wall transformation depth, and thermocouple data. A comprehensive gun erosion model is described for the 120-mm M256 gun with its M829Ax series rounds. In addition, a detailed shot-by-shot erosion modeling prediction is described for retired 120-mm M256 gun tube serial #1988. For this gun tube, the erosion prediction includes the two types of rounds fired, M829 and M829A2, and their three round-conditioning temperatures, hot, ambient, and cold. The gun erosion mechanism consists of heat checking the inert chromium plate, subsequent interfacial degradation of the subsurface gun steel substrate at the chromium crack bases, then chromium platelet spalling, and subsequent bare gun steel gas wash. This gun erosion model correctly calculates and predicts that the worst eroded region is at 1.2 to 2.4 meters from the rear face of the tube. The excessive muzzle wear is by a different, purely mechanical gas wash-free mechanism. Most importantly, given herein are the relative erosion-related effective full-charge values of the fielded M256 gun kinetic energy rounds at various round-conditioning temperatures.

14. SUBJECT TERMS
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13. ABSTRACT (Maximum 200 words)
Most 120-mm M256 guns firing the M829 round as their "hottest" kinetic energy round have been condemned because of fatigue. Despite this fact, it is still important to determine the erosion life of the M829 round, since M256 guns that have fired the most recent kinetic energy rounds (M829A1, M829A2) rely on the M829 round for baseline dispersion testing of that gun. Today this generally results in M256 guns that having an equal mix of M829 and M829A2 rounds, thus necessitating the consideration of M829 round effects for any erosion analysis. Variability exists for M256 guns with M829 rounds depending on round count, round type, round-conditioning temperature, and their order. Distinctive erosion patterns and mechanisms are emerging as our gun erosion database increases for in-service and out-of-service 120-mm M256 tubes with M829 rounds. Our M256/M829 gun system erosion model—with its interior ballistics, thermochemistry, and boundary layer components—is constantly being guided and refined by the erosion and materials analysis data from fired gun tubes. A recent refinement includes improvement of the gun steel subsurface exposure model due to high quality, difficult to obtain data from in-service M256 tubes. Other recent refinements to the boundary layer heat transfer model are based on thermal data from M256 tubes. These refinements include the improvement/incorporation of case gas cooling effects, turbulent gas mixing/heating effects, and a very minor contribution from forcing cone-induced vena contracta cooling effects. These latter refinements are calibrated away from crack walls by positional thermal wall repacking depth, thermal wall transformation depth, and thermocouple data. A comprehensive gun erosion model and multiple single-shot erosion condemnation predictions are described for the 120-mm M256 gun with its M829 round for hot-conditioned rounds only, ambient-conditioned rounds only, cold-conditioned rounds only, and an equal distribution of hot/ambient/cold-conditioned rounds. The gun erosion mechanism consists of heat checking of the inert chromium plate, subsequent interfacial degradation of the subsurface gun steel substrate at the chromium crack bases, then subsequent chromium platelet spalling, and subsequent bare gun steel gas wash. This gun erosion model correctly calculates and predicts that the worst eroded region is at 1.2 to 2.4 meters from the rear face of the tube. The excessive muzzle wear is by a different, purely mechanical gas wash-free mechanism. Most importantly, given herein are the relative erosion related effective full-charge values of the fielded M256 gun kinetic energy rounds at various round-conditioning temperatures.

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